Proceedings of the 29th IEEE International Symposium
on Robot and Human Interactive Communication,
August 31 - September 4, 2020 - Virtual Conference

Acceptance of a minimal design of a human infant for facilitating affective interaction with older adults: A case study toward interactive doll therapy*

Hidenobu Sumioka[1] and Masahiro Shiomi[1] and Nobuo Yamato[2] and Hiroshi Ishiguro[3]

***Abstract*— We introduce a minimal design approach to achieve a robot for interactive doll therapy. Our approach aims for positive interactions with older adults with dementia by just expressing the most basic elements of human-like features and relying on the user's imagination to supplement the missing information. Based on this approach, we developed HIRO, a baby-sized robot with abstract body representation and without face. The recorded voice of a real human infant emitted by robots enhance human-like features of the robot and then facilitate emotional interaction between older people and the robot. A field study showed that HIRO was accepted by older adults with dementia and facilitated positive interaction by stimulating their imagination.**

Fig. 1. A minimal design of a human infant for interactive doll therapy, HIRO

I. INTRODUCTION

Dementia is a major cause of dependency and disability in older adults and significantly impacts them as well as their families, caregivers, and society. 40-50% of those with dementia suffer from cognitive, psychological, and behavioral problems (BPSD), including hallucinations, depression, and agitation. Such problems force caregivers to pay more attention to such people, which increases their burden and the cost of care. Therefore, BPSD reduction is a major social challenge [1]. Although pharmacological interventions are often used for this purpose, non-pharmacological interventions are recommended first to avoid potential side effects [2]. Many attempts related to non-pharmacological interventions have been addressed.

Doll therapy, which usually provides a human baby doll to seniors with dementia, is one of non-pharmacological intervention. Studies reports that some seniors with dementia show such care actions for the dolls as holding, talking, feeding, cuddling, or dressing and then they increase levels of engagement with others and reduce BPSD as a result [3]. Although typical doll therapy uses a baby doll without any interactive functions, robotic technology can enhance the interaction with older people. For example, Babyloid [4], which is a baby robot modeled on a beluga whale baby, is an application for an interactive doll therapy because it can show such reactions as six kinds of emotional facial expressions as well as play a recorded voice of a one-year-old child and move its neck, mouth, and eyes in response to the actions of seniors.

Since typical doll therapy provides no response from the doll, its appearance is the only factor that can be modulated to enhance senior's feeling of human presence. Therefore, they seem to prefer a doll with a more human-like appearance [5]. However, for a baby robot, since it is possible to interact with older adults in a multimodal way, both the interaction and the multimodal information are obviously important and must be designed carefully. One technically-challenging approach is to make every feature as realistic as possible so that the robot actually resembles a human baby. However, such an approach might cause an adaptation gap, which indicates that the differences between the actual functions of artificial agents and those expected by users before their interaction with them affect the users' final impressions of the agents [6]. Another potential problem is the uncanny valley effect, which describes the eeriness and discomfort when we encounter realistic virtual/artificial humans [7]. This approach also increases both the expense and fragility of the robots, adding to the burden of care costs and fueling care staff resistance.

Another approach explores simpler designs to eliminate

*This work was supported by JST CREST Grant Number JPMJCR18A1, Japan

[1]Hidenobu Sumioka and Masahiro Shiomi are with the Advanced Telecommunications Research Institute International, 2-2-2 Hikaridai, Seika-cho, Soraku-gun, Kyoto, Japan, {sumioka,m-shiomi}@atr.jp

[2]Nobuo Yamato is with Japan Advanced Institute of Science and Technology 1-1 Asahidai, Nomi, Ishikawa 923-1292 Japan, yamato@vstone.co.jp

[3]Hiroshi Ishiguro is with the Graduate School of Engineering Science, Osaka University, 1-3 Machikaneyama, Toyonaka, Osaka 560-8531, Japan, ishiguro@sys.es.osaka-u.ac.jp

978-1-7281-6075-7/20/$31.00 ©2020 IEEE

such negative effects described above. This approach also helps to make the user understand the cognitive and socio-emotional information from a robot easily because it eliminates unnecessary elements and clarifies the information to be conveyed. In particular, older adults have problems integrating information from multiple modalities due to cognitive and socio-emotional decline and mental illness [8]. This implies that conveying the information in less modalities makes older adults understand the information easily. Furthermore, it also helps us build a robot which is cost effective and less fragile. Therefore, the investigation of the minimal requirements of an interactive robot for doll therapy is important to realize doll therapy in effective ways.

In this study, we apply the minimal human design approach to an interactive baby robot to create a positive interaction for users by expressing only the minimum elements of human-like features and relying on the user's imagination to supplement the missing information. We developed a teleoperated android named Telenoid as a test bed to investigate its effectiveness with older people with dementia [9], [10] ([11] for a review). Although Telenoid lacks emotional expression functions of its face, older people were able to imagine its smile from the information contained in the voice of the human operator. We expect that the design that facilitates user's imagination to a robot like Telenoid enhances positive attitude toward the robot. Based on a minimal human design approach, we developed HIRO[1]. Although its shape and size resemble a human baby, we eliminated such facial expressions as gazes and emotional expression as well as such detailed body parts as hands. Instead of a simple appearance, we used the recorded voice of an actual human infant with multiple emotional states to facilitate emotional interaction. HIRO vocalizes based on its emotional states, which respond to older adults person's actions as well as its own internal mechanism.

It remains unclear whether this new baby robot will actually be accepted by older people with dementia and how they will interact with it since it has untypical appearance. The aim of this paper is to investigate these points before performing interactive doll therapy, hypothesizing that the baby robot which is designed based on the minimal human design approach induce longer interaction with older adults than typical baby robot. We introduce HIRO and a typical baby robot into an elderly nursing home to investigate their influences on older people through experiments in their living environments. We evaluate whether older adults with dementia show positive interaction with HIRO or typical baby robot at least five minutes. We also observe the interaction between older people and the robots and figure out common and unique responses of older adults to the robots.

II. Related Work

Robot therapy has been proposed with several types of social robots to provide mental support for older adults. Some works suggest that effective interaction with a robot, such as touching and caring for older adults, may affect well-being by reducing anxiety, for example [12], [13].

A seal-shaped companion robot, "PARO", is one of the most famous robots for robotic therapy. Many studies have shown that it provides not only psychological and physiological effects in older adults but also helps them expand their social networks [14]. These effects have been confirmed in Japan and other countries [15]. On the other hand, a study with doll therapy reports that many older people with dementia preferred dolls to stuffed bears in doll therapy [16]. Therefore, an interactive baby robot may be more suitable for dementia sufferers to whom doll therapy is effective.

Babyloid [4], modeled on the beluga whale, is a baby robot that shows potential for interactive doll therapy. It can perform facial expressions with six types of emotions and such multimodal reactions as a recorded voice of a one-year-old and body movements. In a two-week experiment with five healthy, older adults, interaction with Babyloid averaged about seven minutes, and their scores on the Geriatric Depression Scale (GDS), which measures depression, improved after the experiment. However, no studies have been reported that actually involve older adults with dementia. In addition, although various features were implemented, no functional requirements were explored.

We developed a teleoperated android named Telenoid based on a minimal human design approach to support communication with older adults. Telenoid only has minimal functions for communication and a simple movement mechanism for its arms, neck, and mouth. It has no function for emotional expression though it has eye, nose, and mouth. Its appearance is neutral in terms of gender and age. However, the human operator's voice information conveyed from Telenoid allows users to project personal traits and emotional states onto Telenoid. In fact, some older adults claimed that Telenoid smiled during their interactions although such a function is not implemented [11]. Another study described how older people with dementia often made physical contact with Telenoids [10]. Such touch interactions probably increase the intimacy between older adults and robots and strengthen their social bonds [17].

On the other hand, it requires a human operator since Telenoid is a teleoperated robot. However, for older adults with moderate to severe dementia, verbal communication is often difficult, and simpler communication should be sufficient. In addition, previous studies have shown that many such older people treat Telenoid like a toddler even when adult care staffs teleoperated it [9], implying that a more child-specific design that elicits their imagination through simple communication may be sufficient. Therefore, we designed an interactive baby robot based on a minimal design approach.

III. Minimal Design of Human Infant

Figure 1 shows a prototype of the minimal design of a human infant, HIRO (W210 x D165 x H 300 mm and 610 g). Its ABS control module, which is covered with a polyester fabric, includes a computer, a 3-axis accelerometer, and a

[1] HIRO-chan is a commercial version manufactured by Vstone Co., Ltd. https://vstone.co.jp/products/hiro/index.html

Fig. 2. A typical baby robot in Face group

speaker. The module can be removed from its back. HIRO is also equipped with a microphone and a touch sensor, but we did not use them in this study.

Its appearance resembles a human baby. The distinction among its head, torso, and limbs is recognizable but its face is excluded. Previous studies confirmed that a distinction between head and torso is the minimum requirement for enhancing a feeling of a human presence and that the expression of limbs does not significantly enhance human impressions [18]. Although we could have removed the limbs, we left them so that older people can intuitively understand the robot's orientation and its attitude to the interaction. The emotional mismatch between faces and voices complicates the perception of emotion [19], suggesting that if facial expressions are designed poorly, they may interfere with the transmission of emotions and negatively impact the human-robot interaction. In addition, since older adults imagine facial expressions through communication with Telenoid [11], we excluded facial expression to facilitate positive interactions.

Instead of visual information, we enhance humanlikeness in auditory information. We recorded the voice of a human infant about one year old and cut out 91 voice patterns and categorized them into the following emotions: positive: 20; weakly positive: 25; weakly negative: 17; and negative: 29. Positive and negative categories include voice patterns which we was able to recognize as positive and negative clearly. The voice patterns which we relatively recognize as positive and negative were categorized into weakly positive and weakly negative. Weakly positive also included three sounds of baby babbling, which means such meaningless articulated sounds that a human baby utters as "ma ma ma", and the rest of the sounds were different patterns of laughing and crying.

The design of the interaction between older adults and the robot is a critical aspect. The following is the robot's speech generation process. The current internal state ($s_e(t)$) is calculated with previous state $s_e(t-1)$, the output value of the internal generator $s_o(t)$, and the value that represent the effect of the interaction with older adults $s_i(t)$, reflected as sensor information. Based on the sum of these three values, $s_e(t)$ is selected between negative (1) and positive (4), and a current voice is randomly selected from the selected emotional category. For example, if $s_e(t) = 4$, one of the voices classified as positive is randomly selected. In this study, the internal generator generated $+1, 0, -1$ with a probability of $50, 20, 30\%$. The interaction effect $s_i(t)$ was changed based on the L2 norm of three values of the accelerometer so that it reacts when the robot is lifted up or down. If the L2 norm is larger than a certain threshold, we set $s_i(t) = 1$ otherwise $s_i(t) = 0$. This implies that the robot's emotional state is more often positive if there is more interaction from the participant and less often positive if there is less interaction from the participant. If $s_e(t)$ is higher(lower) than 4(1), we set $s_e(t) = 4$ ($s_e(t) = 1$). This processing interval was randomly changed within 2 to 5 seconds. In this study, we set the initial state to $s_e(0) = 1$, which means HIRO has a negative emotional state at beginning of the interaction.

IV. Experiment

HIRO is an interactive doll robot that uses minimal visual information and human-like emotions transmitted by voice to induce positive interaction with older adults. Since this is the first attempt to introduce a faceless robot into elderly care, we addressed the following research questions (RQ) before applying HIRO to practical doll therapy: RQ1) Will it actually be accepted by seniors? RQ2) If it is accepted, will it be more easily accepted than a doll with a typical baby robot, which has more body representations and facial expressions? RQ3) Does it elicit different interaction patterns from a typical baby robot?

A. Participants

Our experiment was carried out in an elderly nursing home in Hyogo Prefecture with 21 senior (18 women) participants. Their average age was 86.6 years (SD:5.4), and their average level of required care (Care Level), which is used in Japan to evaluate how much the person require care service [2], was 3.38 (2-5). Older adults were selected by the nursing home's staffs to join the experiment. All the participants and their families received information and signed an informed consent form approved by the ATR Ethics Committee with their doctor's permission.

B. Procedure

Participants were randomly assigned into two groups: participants in one group (11 participants (2 males)) were given a HIRO (No-face group), and the other group (10 participants (1 male)) were given a robot with a more human-like appearance (a typical robot hereafter), shown in Fig. 2 (Face group). This robot has a smiling face, ears, and fingers. It also has a small camera inside its head, which was not used in this study. Both robots wore identical clothing (Fig. 2). All participants have more than one son or daughter and had experience raising their child except for one participant for

[2] https://www.mhlw.go.jp/english/topics/elderly/care/index.html

each group. The demographic information of the participants in each group is shown in Table I.

We investigated whether the participants would continue to care for their baby robot for five minutes when they were given it by a staff member. This interval was suggested by the care staff as a minimum interval that can reduce their burden. The experiment was carried out in the participants' private rooms. Participants who had no problem walking were asked to sit in the chairs in their room. People in wheelchairs were asked to remain in them. In addition, one bedridden participant in each group joined.

The procedure is as follows. The staff and experimenter entered the participant's room and introduced the robot they were holding and asked the participant to hold and soothe it (pre-interaction phase). This phase helped the participants understand the robot's function. The experimenter began video recording and left the room.

Following a call from the experimenter after about one minute, the staff member asked the participant to continue to care for the robot and left the room, leaving the participant and the robot alone (interaction phase). In this phase, we asked the staff member to stay in the room for a half of participants in each group to exclude the possibility that leaving the participant and the robot alone forces the participant to continue to care for the robot. In this case, the care staff avoided actively interacting with them. During the interaction phase, the experimenter (and the staff member if they had left from the participant's room) observed the situation in the room from outside by an external monitor. After five minutes or after the participant lost interest in the robot, the experimenter (and the staff member if they had left) entered the room, thanked the participant for caring for the robot, retrieved it and the video camera, and left the room. After the experiment, we interviewed the staff members to get their opinions and reactions to the participants' interaction with the robot compared to their normal states. We also collected histories of the robot's emotional states in the interaction phase.

C. Evaluation

We investigated RQ1 by examining whether the older participants hold this robot for five minutes and how they interact with it. We counted the participants who continued to hold HIRO or the typical robot for five minutes and compared the numbers to investigate their acceptance for the robot. We also analyzed the proportion of emotional states selected by the robot during the interaction and examined whether the frequency of the robot's emotional expressions affected the interaction times with older adults to investigate RQ2.

In addition to these quantitative evaluations, we observed the participants' speech and behavior toward the robot to investigate RQ2 and RQ3 and extracted the shared and different characteristics of the participant responses. We also interviewed the care staff who observed the reactions of the participants and compared their impressions to their normal reactions of the participants.

TABLE I
DEMOGRAPHIC INFORMATION OF PARTICIPANTS

Group	Age ± SD	Care Level ± SD
No-face	86.3 ± 4.21	3.36 ± 0.81
Face	86.9 ± 6.62	3.4 ± 0.97

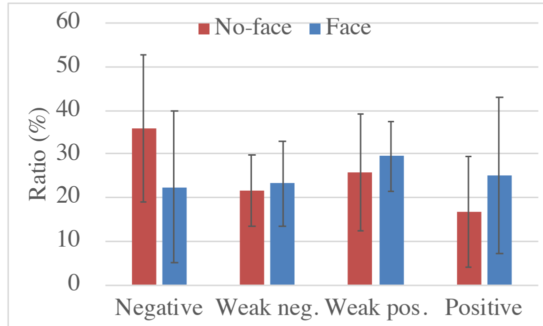


Fig. 3. Average ratio of robot's emotional states during interaction

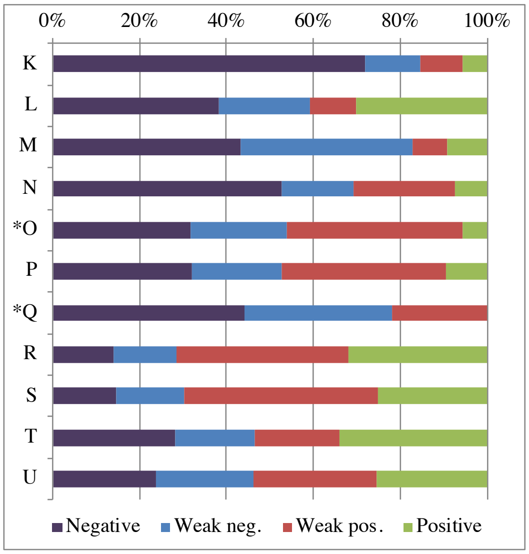
V. RESULT

A. Quantitative results

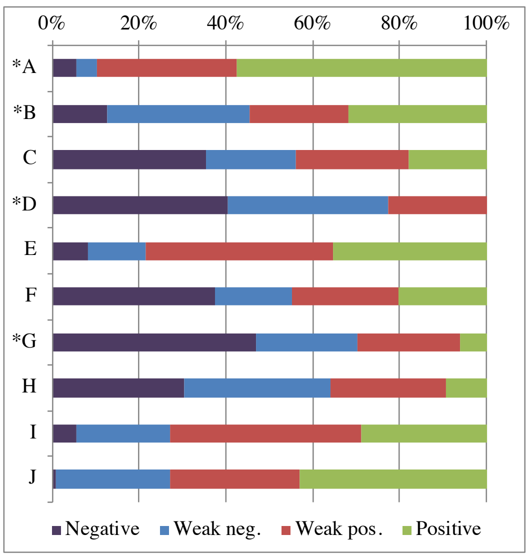
Regardless of the group, most participants positively enjoyed engaging with the robot. 60% in the Face group and 81.8% in the No-face group continued to hold it for five minutes. One sample proportion test showed that the No-face group was significantly higher than 50% ($\chi^2 = 4.45, p = .017$) while the Face group was not ($\chi^2 = .4, p = .26$). In the Face group, one participant completely stopped holding the robot, and two participants called the staff member to remove the robot after caring for it for less than five minutes. Another participant returned the robot because it started crying. In the No-face group, one participant completely stopped holding the robot and one participant fell asleep during caring for it. Although more participants continued to care for the robot in the No-face group, we found no statistically significant difference in terms of proportions using the chi-square test ($\chi^2 = 1.22, p = .27$).

We investigated the proportion of the robot's emotional states that occurred during the interaction to determine whether there was a difference in the way participants engaged with the robot across the conditions. Figure 3 shows the average of the ratio of the emotional states of the robots over a five-minute period for each group. Since the normality in the negative and positive states was confirmed with the Shapiro-Wilk test, we did a Welch's t-test, and a Mann-Whitney's U test for weak negative and weak positive states. Although the No-face group tended to have more negative states than the Face group ($t(18.7) = -1.80, p = .089, d = .79$), there were no significant differences (weak negative: $W = 63, p = .60, r = .17$; weak positive: $W = 68, p = .39, r = .28$; positive: $t(16.1) = 1.23, p = .24, d = .55$).

Figure 4 shows the percentage of emotional states that occurred during the interaction with each participant. An asterisk indicates participants who did not care for the robot for the entire five minutes. We found no distinctive



(a) No-Face group



(b) Face group

Fig. 4. Ratio of robot's emotional state during interaction. Letters indicate each participant. * shows participant who failed to care for robot for entire five min.

differences between the groups or whether they interacted with it for the entire five minutes.

B. Qualitative results

All participants who interacted with HIRO or the typical robot for five minutes showed positive attitudes toward them. They engaged as they might with a typical actual infant: sang songs, lifted the robot up, kissed, cuddled, and rocked it. Even in the No-face group, participants interacted while looking at the robot's face, even though it has no facial expression. The participants who were able to communicate addressed it regardless of the condition: "*It's so cute*" or "*What's your name?*" They talked to it about things related to the robot and themselves.

The participants also responded to the robot's crying and laughing:"*Don't cry*" or "*It's laughing*." They also tried to interpret the robot's babbling. For example, participant R said, "*Don't say no*" to the robot's babbling, and participant L said, "*It says that its name is Kentaro*." An older adult with severe dementia (participant O) who had difficulty communicating parroted the robot's voice.

In the No-face group, participants L and T talked about HIRO's face. Participant T, looking at HIRO, remarked that "*he has no eyes or mouth!*" Participant L also lamented that he had no eyes or mouth while pointing at his face. However, the lack of facial expressions did not interfere with their interactions because they both positively cared for HIRO.

Many of the participants seemed to be actively caring for the robot even though they knew that it was a robot. For example, participant T said, "*It's sturdy*." Participant E asked, "*What's the doll's name?*" On the other hand, two participants seemed confused whether the robot was actually human. For example, when HIRO started crying, participant N who has severe dementia in the No-face group said, "*I can't breastfeed him*," which implies that she thought HIRO was hungry. Participant C who has severe dementia in the Face group repeatedly touched the robot's crotch and tried to undress it when it started crying. The staff member thought that "*it looked like she was checking the robot's diaper*."

VI. DISCUSSION

We introduced a minimal design approach and developed an interactive doll called HIRO to investigate the necessary elements of a robot for interactive doll therapy. HIRO had minimal representation as a human baby and no facial expression. Nevertheless, the older adults continued to hold ito and showed positive interaction with it. One sample proportion test also supports this. Therefore, we can answer yes to RQ1: the older adults accept HIRO.

We developed RQ2 and RQ3, expecting that eliminating non-essential information and allowing users to imagine the missing information would promote positive interaction and be more acceptable to a wider range of older adults with dementia. Unfortunately, we found no significant effect compared to the typical robot, which means that we should answer no to RQ2. The participants' observations confirmed that both robots elicited positive attitude and a variety of imaginative reactions from older adults, which indicate RQ3 should be answered with no. One possibility is that since our experiment was only five minutes long, its effect may not have had a significant impact. We need to test longer and multiple interactions.

Another possibility is that the lack of information about appearance may not have had a great effect because we used an actual baby's voice. Japanese people tend to rely more on auditory information than European people when visual and auditory information are presented simultaneously [20]. In addition, since dolls with more human-like features are preferred in doll therapy [5], perhaps the interaction through human voice emitted by robots has become primary for older people with dementia. It will be interesting to examine whether a similar effect is achieved in the future when low quality speech or synthetic speech are used.

This result also suggests that voice-specific interactions such as HIRO may be more effective with European people. Although no cultural differences have been found in previous studies with a teleoperated android, perhaps Telenoid's human-like appearance will work effectively for European people, and its human voice is effective in Japanese. We are looking forward to investigating cultural differences in robot design guidelines in interactive doll therapy.

One advantage of baby robots that can make multimodal, emotional expressions, such as Babyloid, is that they can expand the range of older adults who can be supported. For example, HIRO and Telenoid can not facilitate emotional interactions with deaf older people. In this case, interaction through facial expressions is generally effective although the intuitive design of facial expressions for older adults should be explored for smooth emotional interaction.

Multimodal interaction is important for rich emotional interaction, and humanoid robots are an effective means to do so. But on the other hand, increasing the quality of every modality increases the cost and fragility of robots. The minimal design approach, which searches for the minimum necessary elements to facilitate emotional interaction, limits the robot's functions, resulting in a cheaper and more robust machine. In fact, HIRO-chan, the product version of HIRO, is less expensive (about 5000 yen) than other robots and interactive toys. Since it is covered with a soft material, it is reasonably safe from being broken even when it is handled carelessly or roughly. Therefore, care staff members can use it with less concern about damage.

There are several limitations in this study. First, sample size is relatively small and the degree of dementia was not balanced across the groups. Future experiments with larger samples are needed to control the participants' dementia levels and measure them with objective indicators such as Severe Mini Mental State Examination (sMMSE). We must also objectively assess whether HIRO actually reduces BPSD symptoms. In addition, due to such large individual differences, we must perform validation in a within-subject design for future research.

VII. CONCLUSIONS

We introduced a minimal design approach to achieve a robot for interactive doll therapy. Based on this approach, we developed HIRO, a baby-sized robot with an abstract body representation and without facial expressions. Emotional interaction was achieved with the voice of an actual baby to activate the imagination of seniors with dementia. Field work for older adults with dementia showed that they accepted HIRO. Additional experiments with more samples are needed in the future. In addition, we must verify whether it actually reduces BPSD symptoms using objective indicators.

ACKNOWLEDGMENT

We thank K. Kawashima, S. Yamauchi, M. Okubo, and S. Hiramatsu for helping data analysis and system development. We also thank all staffs and residents in Ryusei Fukushikai Yume paratice for helping our experiment.

REFERENCES

[1] J. Cerejeira, L. Lagarto, and E. B. Mukaetova-Ladinska, "Behavioral and Psychological Symptoms of Dementia," *Front. Neurol.*, vol. 3, 2012.

[2] M. Azermai, M. Petrovic, M. M. Elseviers, J. Bourgeois, L. M. Van Bortel, and R. H. Vander Stichele, "Systematic appraisal of dementia guidelines for the management of behavioural and psychological symptoms," *Ageing Research Reviews*, vol. 11, no. 1, pp. 78–86, Jan. 2012.

[3] G. Mitchell, B. McCormack, and T. McCance, "Therapeutic use of dolls for people living with dementia: A critical review of the literature," *Dementia*, vol. 15, no. 5, pp. 976–1001, Sept. 2016.

[4] M. Kanoh, "A Robot as"Receiver of Care" in Symbiosis with People," *Journal of Japan Society for Fuzzy Theory and Intelligent Informatics*, vol. 27, no. 6, pp. 193–201, 2015.

[5] T. Tamura, K. Nakajima, M. Nambu, K. Nakamura, S. Yonemitsu, A. Itoh, Y. Higashi, T. Fujimoto, and H. Uno, "Baby dolls as therapeutic tools for severe dementia patients," *Gerontechnology*, vol. 1, no. 2, pp. 111–118, Apr. 2001.

[6] T. Komatsu, "Adaptation gap hypothesis: How differences between users' expected and perceived agent functions affect their subjective impression," *Journal of Systemics, Cybernetics and Informatics*, vol. 9, no. 1, pp. 67–74, 2011.

[7] M. Mori, K. MacDorman, and N. Kageki, "The Uncanny Valley," *IEEE Robot. Autom. Mag.*, vol. 19, no. 2, pp. 98–100, June 2012.

[8] T. Ruffman, J. D. Henry, V. Livingstone, and L. H. Phillips, "A meta-analytic review of emotion recognition and aging: Implications for neuropsychological models of aging," *Neuroscience & Biobehavioral Reviews*, vol. 32, no. 4, pp. 863–881, Jan. 2008.

[9] R. Yamazaki, S. Nishio, K. Ogawa, and H. Ishigur, "Teleoperated android as an embodied communication medium: A case study with demented elderlies in a care facility," in *2012 IEEE RO-MAN: The 21st IEEE International Symposium on Robot and Human Interactive Communication*. Paris, France: IEEE, Sept. 2012, pp. 1066–1071.

[10] K. Kuwamura, S. Nishio, and S. Sato, "Can We Talk through a Robot As if Face-to-Face? Long-Term Fieldwork Using Teleoperated Robot for Seniors with Alzheimer's Disease," *Front. Psychol.*, vol. 7, 2016.

[11] H. Sumioka, S. Nishio, T. Minato, R. Yamazaki, and H. Ishiguro, "Minimal Human Design Approach for sonzai-kan Media: Investigation of a Feeling of Human Presence," *Cognitive Computation*, vol. 6, no. 4, pp. 760–774, Dec. 2014.

[12] J. Broekens, M. Heerink, and H. Rosendal, "Assistive social robots in elderly care: A review," *Gerontechnology*, vol. 8, no. 2, pp. 94–103, Apr. 2009.

[13] L. Pu, W. Moyle, C. Jones, and M. Todorovic, "The Effectiveness of Social Robots for Older Adults: A Systematic Review and Meta-Analysis of Randomized Controlled Studies," *The Gerontologist*, vol. 59, no. 1, pp. e37–e51, Jan. 2019.

[14] K. Wada and T. Shibata, "Living With Seal Robots—Its Sociopsychological and Physiological Influences on the Elderly at a Care House," *IEEE Transactions on Robotics*, vol. 23, no. 5, pp. 972–980, Oct. 2007.

[15] T. Shibata, K. Wada, Y. Ikeda, and S. Sabanovic, "Cross-Cultural Studies on Subjective Evaluation of a Seal Robot," *Advanced Robotics*, vol. 23, no. 4, pp. 443–458, Jan. 2009.

[16] I. A. James, L. Mackenzie, and E. Mukaetova-Ladinska, "Doll use in care homes for people with dementia," *International Journal of Geriatric Psychiatry*, vol. 21, no. 11, pp. 1093–1098, 2006.

[17] M. Okubo, H. Sumioka, S. Keshmiri, and H. Ishiguro, "Intimate Touch Conversation through Teleoperated Android: Toward Enhancement of Interpersonal Closeness in Elderly People," in *2018 27th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN)*. Nanjing: IEEE, Aug. 2018, pp. 23–28.

[18] H. Sumioka, K. Koda, S. Nishio, T. Minato, and H. Ishiguro, "Revisiting ancient design of human form for communication avatar: Design considerations from chronological development of dogu," in *IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN)*, Aug. 2013, pp. 726–731.

[19] B. de Gelder and J. Vroomen, "The perception of emotions by ear and by eye," *Cogn. Emot.*, vol. 14, no. 3, pp. 289–311, May 2000.

[20] A. Tanaka, A. Koizumi, H. Imai, S. Hiramatsu, E. Hiramoto, and B. de Gelder, "I Feel Your Voice: Cultural Differences in the Multisensory Perception of Emotion," *Psychological Science*, vol. 21, no. 9, pp. 1259–1262, Sept. 2010.